HIGH-PRESSURE GAS FROM LITHIUM

HYDRIDE AND SEA WATER

by

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ABSTRACT. Tests were made to determine the
quantity and rate of gas produced from the lithium
hydride–sea water reaction. The effects of par-
ticle size, pressure, temperature, water compo-
sition, water–lithium hydride ratio, and additives
to the lithium hydride were investigated. In addi-
tion, a gas inflation system for torpedo recovery
using lithium hydride was designed and tested in
the ocean. Lithium hydride and water were found
to react completely at a ratio of 25 (or more)
parts water: 1.0 part lithium hydride, by weight.
The effects of other variables on the reaction
were minor. The lithium hydride torpedo-recovery
system successfully raised 50 pounds from a depth
of 2,600 feet.

U.S. NAVAL ORDNANCE TEST STATION

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U. S. NAVAL ORDNANCE TEST STATION

AN ACTIVITY OF THE BUREAU OF NAVAL WEAPONS

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FOREWORD

This report presents lithium hydride-sea water reaction test results used to develop an inflated-gas-bag torpedo recovery system. As a result of the study, a successful recovery system was designed, tested, and patented.

The study was performed at the U. S. Naval Ordnance Test Station under Bureau of Naval Weapons Task Assignment RUTO-3E-000/216 1/E008-06-02 during experimentation on the deep-operating electric torpedo investigation program. The work was done during Fiscal Years 1962 - 1965.

This report represents the considered opinions of the Product Engineering Division.

INTRODUCTION

High-pressure gases have many underwater applications. Submarines use high-pressure gas for blowing ballast tanks and firing weapons. Underwater recovery devices use them to create buoyancy, while other possible uses include device actuation, balloon inflation, and even employment as engine fuel. This report presents the results of tests leading to the development of an underwater recovery device depending on the generation of hydrogen gas by a reaction of lithium hydride and sea water.

While many systems are possible for generating gas, the most successful must meet the criteria of cost, reliability, weight, space requirements, storage stability, and safety. Representative systems are given in the following table, and are designed to yield 2.0 ft^3 at 32-atmosphere pressure.

	Weight of material, lb	Estimated weight of apparatus, lb	Volume of material, in^2
Burning rocket grain to form a gas	5.36	5	98
Pressurized gas: helium at 5,000 psi	0.71	18	400
Liquid CO_2	10.0	2	300
$Fe(CO)5 + heat \rightarrow Fe + 5CO$	7.0	3	135
Hydrazine decomposition: $3N_2H_4 \rightarrow NH_3 + 2.5N_2 + 4.5H_2$	2.5	1	70
Lithium hydride plus free water: $LiH + H_2O \rightarrow LiOH + H_2$	1.35	0.5	50

All calculations are based upon the gas being at a temperature of 70°F. If the gas were heated to 300°F, only two-thirds as much material and space in each method would be required. All values given are approximate.

Method No. 6 was adopted, as it offered the most promise in terms of simplicity, weight, and space requirements, particularly with free ocean water as one of the reactants. Of all economically feasible substances, lithium hydride yields the most gas per unit of weight and volume. Studies were therefore made to develop a recovery system using lithium hydride. (It might be mentioned that lithium borohydride yields more gas, but is very expensive.)

EXPERIMENTAL PROGRAM

The feasibility studies were broken down into two phases: (1) physicochemical investigations of the chemical reaction; and (2) ocean range tests of the mechanical design concepts of a complete gas-inflation system for torpedo recovery.

PHYSICOCHEMICAL INVESTIGATIONS

The hydrolysis of lithium hydride by water can be written completely as follows:

$$LiH(solid) + H_2O(liquid) \rightarrow LiOH(aqueous) + H_2(gas)$$

Since this reaction is heterogeneous, the area of the solid-liquid interface obviously will be a dominant factor in the reaction rate. In all, three factors were considered as affecting reaction rate and completeness of reaction under actual operating conditions: (1) the surface area of the solid-liquid interface; (2) the thermodynamic variable of pressure; and (3) the thermodynamic variable of temperature. The effects of additives on electrolytes dissolved in sea water were also investigated.

All laboratory experiments to investigate the effect of the above variables on reaction rate and equilibrium were conducted in a high-pressure autoclave. Lithium hydride was placed in a wire basket, which, in turn, was suspended above the waterline in the autoclave. After sealing, the reaction was initiated by inverting the autoclave. The course of reaction was followed by a rise in pressure owing to hydrogen liberation. The following sections summarize the investigations by category.

Completeness of Reaction at Equilibrium. For these preliminary tests, the apparatus consisted of a 42-cc volume pressure bottle, to which was attached a pressure gage. In most of the experiments, 5.0 cc of water was put in the bottle, and various amounts of lithium hydride were suspended in a cup above the water. The bottle was then closed, inverted, and shaken to mix the components. The pressure readings were recorded and compared with the theoretical pressures. The test results were as follows:

LiH, gram	H₂O, cc	H₂, psi	Calculated H₂, psi
0.10	5	105	107
0.15	5	155	161
0.20	5	205	214
0.34	5	270	364

A nearly theoretical amount of gaseous hydrogen was developed when the amount of lithium hydride was limited to 0.20 gram or less. However, when 0.34 gram was used, only three-fourths the theoretical amount of gas was developed. When the bottle containing this larger amount of lithium hydride was opened, it was found that much of the substance had not reacted with the water. However, the reaction resumed with the addition of more water. This lead to the suspicion that a theoretical amount of gas could be produced only if there were a large excess of water. To check this theory, 1.0 gram of lithium hydride was placed in an open beaker, and water was added slowly until the reaction ceased. Cessation occurred after 25 cc of water had been added, proving that a large excess is necessary to obtain maximum gas.

One experiment was run by reversing the normal process; i.e., the positions of the water and the lithium hydride in the apparatus were reversed. Five grams of hydride was put in the bottle, and 0.40 cc of water was put in the cup. The apparatus was shaken vigorously, producing a gage reading of 170 psi. The calculated reading had been approximately 300 psi, or about 1.8 times the actual reading. Thus, this result reinforced the previous conclusions.

Effect of Particle Size on Reaction Rate. The autoclave used in this series, as well s in all the remaining tests, was a 1,500-cc pressure vessel. The pressure gage was attached to a recorder, so that the change in pressure with time could be determined. A summary of all these tests is given in Table 1, and the results of the first six are plotted in Fig. 1.

The effect of particle size can be seen in Table 1 and Fig. 1 by comparing Test 2, in which coarse particles (0.25-inch pellets) were utilized, with Test 5, which employed fine particles of -16 to +40 mesh. In 30 seconds, the fine particles had reacted by 97 percent, while the coarse pellets had reacted only 60 percent.

Because a torpedo operating at maximum depth could be descending at a rate of 30 ft/sec shortly after run completion, a fast-reacting hydride form would be desirable to produce maximum flotation gas quickly and halt the descent before crush depth is reached.

Effect of Pressure on Reaction Rate and Equilibrium. The effect of pressure on reaction rate also can be seen in Fig. 1 and Table 1. Tests 5 and 6 were made under nearly identical conditions. Test 6 involved the use of sea water pressurized to 1,000 psi with nitrogen prior

TABLE 1. Summary of Experiments With 1,500-cc Pressure Chamber

In all tests, 750 cc of sea water used, except as noted.

Test no.	Weight of LiH, grams, and type	Weight of oil, grams, and type	Weight of residue, grams	Percent gas generated in 30 sec	Percent gas generated in 1.0 min	Percent gas generated, total	Remarks
1	6.0 coarse	None	None	75	95	99	Fresh water
2	15 coarse	None	None	60	87	107	Fresh water
3	30 coarse	None	None	60	87	123	Fresh water
4	30 coarse	None	None	55	69	101	500 cc fresh water
5	15 fine	None	None	97	104	106	750 cc fresh water
6	15 fine	None	15	120	120	120	Sea water initially prepressurized 1,000 psi
7	15 fine	7.5 motor	49	46	57	83	Sea water prepressurized 1,000 psi
8	7.5 fine	3.7 motor	7.0	57	70	83	Sea water
9	7.5 fine	3.8 motor	1.0	76	85	94	Sea water
10	15 fine	8.3 motor plus 1.5 grams detergent	21	63	100	100	Sea water prepressurized 1,000 psi
11	15 fine	7.5 paint thinner	...	107	110	110	Sea water prepressurized 1,000 psi
12	30 coarse	15 hydraulic	...	30	43	79	Sea water prepressurized 1,000 psi
13	15 fine	7.5 diesel	21	127	127	127	Sea water prepressurized 1,000 psi
14	15 fine	7.5 hydraulic	32	68	101	104	Sea water prepressurized 1,000 psi
15	15 fine	7.5 DC200	8.5	...	...	80	Sea water prepressurized 1,000 psi
16	15 fine	7.5 DC200	26	37	101	101	Sea water prepressurized 1,000 psi
17	7.5 coarse	6.0 paint thinner	6.0	...	...	...	Sea water prepressurized 1,000 psi
18	7.5 fine	7.5 hydraulic	...	...	...	80	Sea water prepressurized 1,000 psi
19	15 coarse	7.5 paint thinner	25	65	92	107	Sea water prepressurized 150 lb
20	30 fine	10 paint thinner	28	60	110	110	Sea water prepressurized 165 lb

FIG. 1. Reaction Rate of Lithium Hydride and Water.
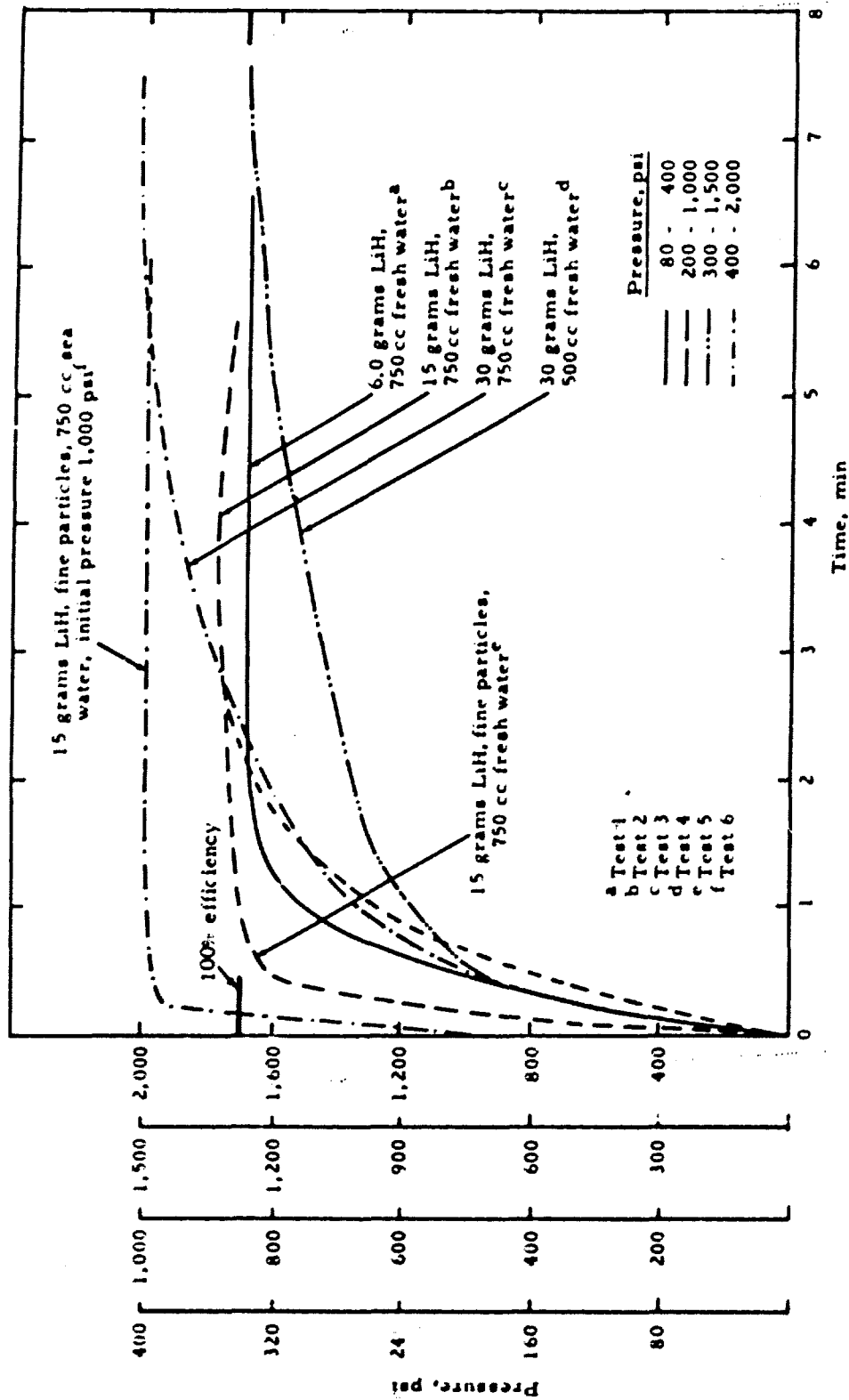
NOTE: Results of the first six tests are plotted to facilitate comparison. Four different pressure scales are used on the graph, so that the 100% efficiency level for each curve is at the same height. Where more than 100% efficiency is indicated, the anomaly may be attributed to heating of the gas in the reaction.

to commencement, while Test 5 was performed at atmospheric pressure with fresh water. Test 6 was approximately 30 percent more effective than Test 5. Although this phenomenon is not thoroughly understood, it is probably due to a surface-passivation effect brought about by the absorbed hydrogen at the LiH–H_2O interface. It is likely that this effect is suppressed at higher pressures, permitting reactions to occur more rapidly.

High pressures, such as those encountered at great depths, would affect the equilibrium of the LiH–H_2O reaction as written, since the final equilibrium point would be pressure-dependent owing to the Le Chatelier effect of high hydrogen backpressure. However, calculations show that high pressures will have little actual effect on shifting the final equilibrium. This conclusion is borne out by comparing Curves 5 and 6 in Fig. 1.

The effect of pressure can also be seen by comparing Tests 1 and 3. In Test 3, five times as much LiH completed reaction, and more than five times as much pressure was generated, as compared with Test 1. Part of this extra pressure in Test 3 was due to heat generated by the reaction of the larger amount of LiH.

Effect of Temperature. Because of the large amount of energy rapidly released during the reaction, and because of the attendant difficulty of maintaining constant temperature conditions, the exact effects of temperature on reaction rate were difficult to determine experimentally. However, assuming (1) that the entire heat of reaction is transferred to the surrounding water, and (2) that a ratio by weight of LiH to H_2O of 1 : 25 exists under actual operating conditions, a total temperature rise of 300°F (approximately 150°C) would result. Assuming that the average temperature over the course of the reaction approximates the arithmetical mean of ambient and final temperature, an increase in reaction rate by a factor of 7 - 8 would be expected. The effect on final equilibrium of a temperature rise of this magnitude would be negligible.

A lithium hydride reaction with a smaller quantity of water would produce greater heat. Calculations indicate that a temperature of more than 3,000°F is possible. Experimental results indicate that reaction rate and temperature are increased the finer the particle size, the higher the pressure, and the larger the amount of reactant. The basic problem is to achieve a rapid reaction, at the same time transferring the generated heat to the water.

Effect of Sea Water Electrolytes. The principle effect noted in tests performed with sea water (as opposed to fresh water) was the presence of insoluble precipitates upon completion of the reaction. Although these precipitates are troublesome insofar as they must be taken into account in mechanical design situations, they do not seem to affect equilibrium or reaction rate appreciably.

Effect of LiH–H_2O Ratio. Comparing Tests 1, 2, 3, and 4 in Table 1 and Fig. 1, it is seen that the lithium hydride–water ratio had little effect, except when fewer than 25 parts water by weight were used

with one part of LiH. In Test 4, a 16:1 ratio was used, and less hydrogen was developed than in Test 3, in which a 25:1 LiH–H_2O ratio was used.

Effect of Additives to the Lithium Hydride. In range testing an experimental apparatus (which will be described later in this report), several difficulties arose in the use of pure lithium hydride. First, the local heat of the reaction was so great when quantities of more than a pound were employed that the rubber bag used to contain the reaction was burned in spots. Second, the water pressure at great depths tended to compress the granular LiH into one solid mass. Third, water pressure also made it difficult to remove the lid from the mouth of the bag and allow water to enter. For these reasons, a nonreactive liquid additive was considered desirable. The additive would slow the reaction rate, so that formation of local hot spots would be minimized, and, being a liquid, would prevent compression of the LiH and balance the hydrostatic pressure, making lid removal easier.

Test results with a number of additives are given in Table 1. With SAE 30 motor oil, approximately 75 percent of the LiH reacted within one minute. With a detergent added to the oil, 100 percent reacted within one minute.

Using paint thinner as an additive, LiH reacted approximately as fast as with no additive at all. With DC200 oil, the rate was a little slower than with hydraulic oil. It should be pointed out that only a few liquid additives can be used with LiH. Acetone, alcohol, and glycerine all react with the compound. However, there is apparently no reaction with hydrocarbons such as kerosene.

RANGE TESTS OF MECHANICAL DESIGN CONCEPTS

Flexible Bag Arrangement. Several design concepts that would permit the utilization of the lithium hydride–sea water reaction in a torpedo recovery system were investigated. The first arrangement was to place the lithium hydride in a flexible rubber bag, using a pump to supply the sea water (Fig. 2). The mouth of the bag was sealed with a fragile rubber diaphragm. When water pressure developed by the pump broke the diaphragm, the bag filled and the reaction took place. While this concept worked satisfactorily in tests at the Naval Ordnance Test Station's Morris Dam facility, it was rejected because of the excessive weight of the pump, motor, and power source.

Simple U-Frame and Bag Mechanism. The next concept was to force water into the bag by means of the torpedo's motion through the water. The proposed system would consist of a sealed, flexible bag partially filled with lithium hydride. The bag would be folded inside a cavity in the torpedo's exercise head. The system would go into operation when (1) the bag was ejected from the moving torpedo, (2) a
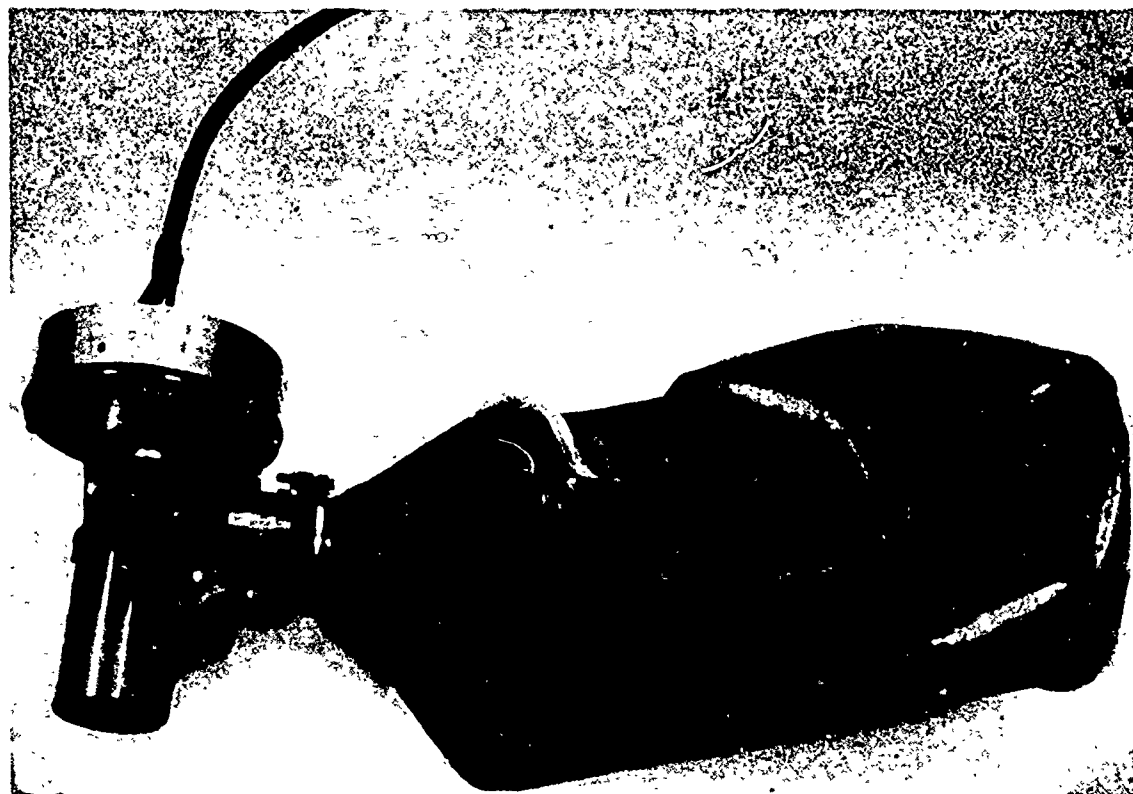
FIG. 2. The Pump-and-Bag Recovery System.

stopper was removed from the mouth of the bag, and (3) sea water flowed into the mouth of the moving bag, which would be attached to the torpedo by means of a strong cord (see Fig. 3).

The water would flow into the bag, like air into a parachute, so long as the torpedo moved and until the bag became filled with the gas-water mixture. Excessive water inflow would be expelled by the liberated hydrogen, so that it could not interfere with torpedo buoyancy. By using fine particles of lithium hydride, the reaction could be completed in 15 to 60 seconds.

A simplified version of this concept was tested (Fig. 4). It consists of a 1.0-ft^3 bag containing a small amount of LiH. Attached to the bag is a U-frame holding a cylinder. The mouth of the bag is sealed with a lightweight stopper, which is pulled out by a piston activated by sea water pressure. The piston is prevented from moving by a shear pin. When the desired depth is reached, the pressure on the piston shears the pin so that the piston moves rapidly down the long cylinder, pulling the cord attached to the stopper. (In early tests, nylon cord broke because of the piston's rapid movement. Rubber strands cut from an inner tube replaced the nylon cord, and functioned without breaking in pressure-chamber tests.) The device was successful in tests at Morris
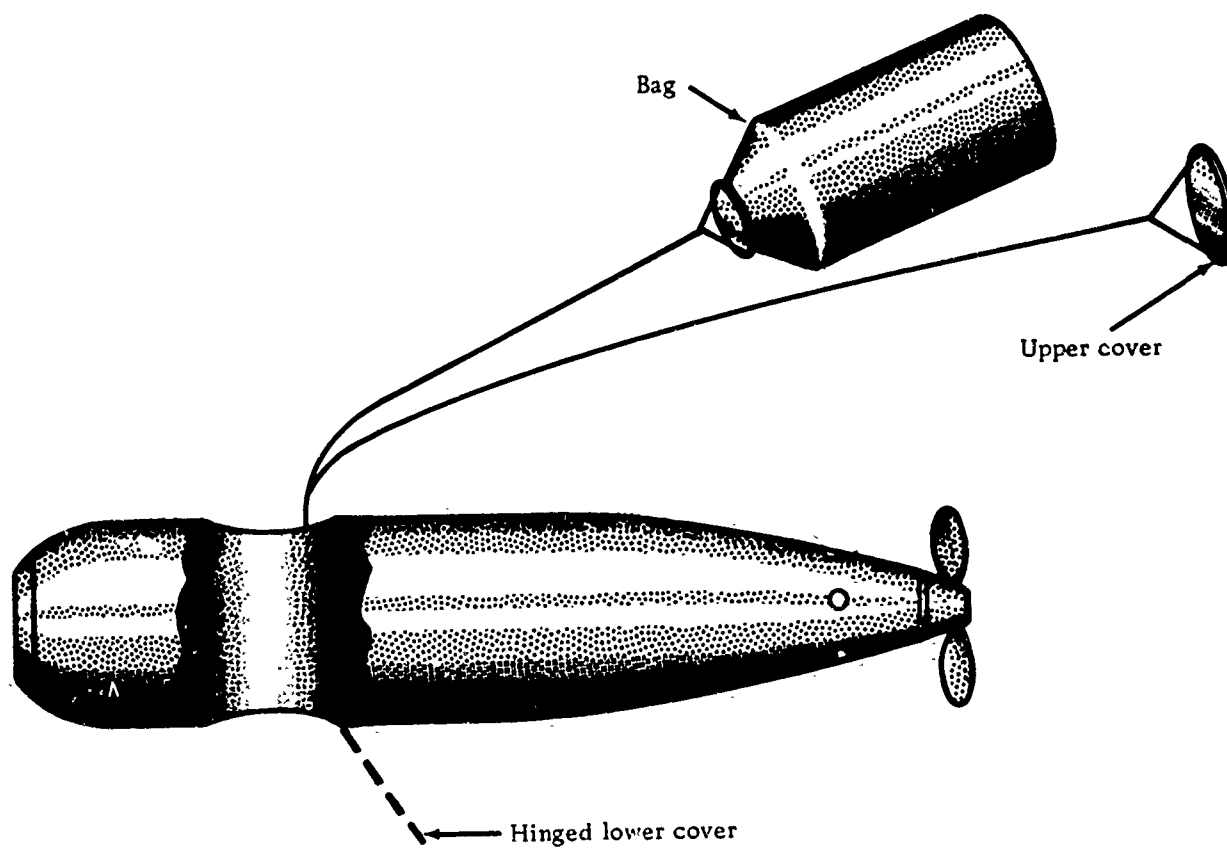
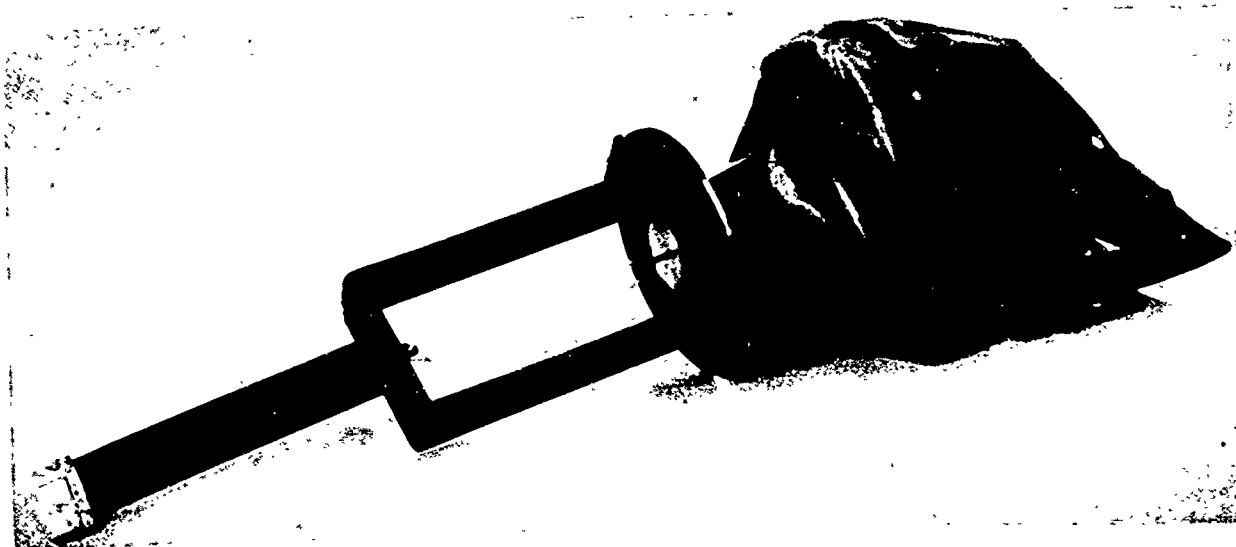FIG. 3.   ·ating Schematic, Torpedo-Shaped Recovery System.

FIG. 4.   U-Frame-and-Bag Recovery Mechanism.

Dam and in the Catalina Channel off Long Beach, where it retrieved a 35-lb weight from a depth of 600 ft (Table 2, Test 4).

Bag-in-Container Mechanism. After proof of the simplified design, a more complex mechanism closely simulating an actual proposed recovery system was constructed (Fig. 5). The device consists of a 10-in.-diameter aluminum cylinder, 10 in. high, with the bottom end closed by a perforated aluminum plate. Inside of the cylinder, there is a concave, cone-shaped chamber formed from plaster, into which is folded the bag containing the lithium hydride. The cylinder is covered with a panel of 3/4-in.-thick plywood. Lines from the cover pass under the bag to a fastening point near the top of the cylinder. As the 42-lb device descends, water pressure on a piston shears a pin, allowing the piston to move and pull a rubber strand, which in turn actuates a spring loaded retaining bolt, releasing the plywood cover. The force of the water carrying away the buoyant cover then pulls the bag out of the cylinder. The force of the moving water on a drag parachute attached to the bag then removes the plug from the bag's mouth. Water enters, gas is generated, and the inflated bag raises the test device to the surface. Tests using this mechanism were successful; a summary of all tests is given in Table 2.

It is seen that in every one of the 30 tests, the bag inflated either at the proper depth or near the surface. When the bag did not inflate at the proper depth, the difficulty arose as a result of a mechanical malfunction. Another problem was excessive heat from the reaction, which tended to burn the bag. For quantities of lithium hydride smaller than 2 lb, the heat problem was solved by mixing the substance with SAE 30 motor oil.

It is worthwhile to recount chronologically the difficulties encountered during early testing of the relatively complex system illustrated in Fig. 5. On Test No. 7, the first time the apparatus was tried in the ocean, the trigger activated as the device was being lowered into the water. The bag flooded, and the LiH began generating gas. The hydrogen filled the bag, pushing all the unreacted LiH against a screen which had been soldered to the mouth of the bag to keep undesirable foreign matter out. This stoppage prevented the rapidly generating gas from escaping and the bag burst. To prevent similar occurrences on later runs, the screen was modified so that it would be expelled under pressure.

In the next test, No. 8, it is believed that the plug in the mouth of the bag was not immediately pulled out, because the bag did not fill with gas until it was pulled to the surface. To exert more pulling force on the plug, a parachute was added for all subsequent tests.

In Test No. 9, the apparatus surfaced despite a hole burned in the neck of the bag by reaction heat. To prevent reoccurrence, a three-piece bag was adopted. This consisted of an outer cloth bag to contain the pressure, a rubber bladder, and an inner cloth bag to prevent burning of the rubber. This configuration worked in Tests No. 10 and

TABLE 2. Summary of Recovery Tests

Test no.	Apparatus	Location	Negative buoyancy, lb	Depth, ft	Amount LiH, lb	Results
1	Pump and bag	Morris Dam	20	32	0.2	Diaphragm leaked; bag inflated at surface
2	Pump and bag	Morris Dam	20	32	0.2	Came up OK
3	U-frame and bag	Morris Dam	15	100	0.5	Came up OK
4	U-frame and bag	Long Beach	35	600	1.0	Came up OK
5	Bag in container; hole in cover	Morris Dam	25	100	0.5	Came up OK
6	Bag in container	Morris Dam	25	100	0.1	Stuck on bottom; came up after pull on rope
7	Bag in container	Long Beach	35	600	1.0	Activated at surface; bag burst; pop-out screen used on all subsequent tests
8	Bag in container	Long Beach	35	600	1.0	Did not activate until bag was being pulled out of water; parachute added on all subsequent tests
9	Bag in container	Long Beach	35	600	1.0	Came up OK; bag burned at neck; hard residue
10	Bag in container; inner liner	Morris Dam	35	100	0.1	Bag stuck on bottom; came up after pull on rope
11	Bag in container; inner liner	Morris Dam	35	100	0.1	Came up OK
12	Bag in container; inner liner	Long Beach	35	600	1.0	Did not activate until pulled near surface; bag stuck to wax
13	Bag in container; inner liner	Long Beach	35	600	1.0	Came up OK; two explosions; bag burned; inner liner no longer used
14	U-frame and bag	Long Beach	25	600	0.25	Came up OK
15	U-frame and bag	Long Beach	25	600	1.0 in oil	Bag started up; pulled from frame
16	U-frame and bag	Long Beach	25	600	1.0 in oil	Came up OK
17	U-frame and bag	Long Beach	25	600	1.5 in oil	Came up OK

TABLE 2. (Contd.)

Test no.	Apparatus	Location	Negative buoyancy, lb	Depth, ft	Amount LiH, lb	Results
18	Bag in container	Long Beach	35	600	1.0 in oil	Came up OK
19	Bag in container	Long Beach	35	600	1.0 in oil	Came up OK
20	Bag in container	Long Beach	35	1,200	1.0 in oil	Came up OK; force of descending piston separated release mechanism and weight
21	Bag in container	Long Beach	50	2,650	1.75 in oil	Came up OK; hard residue in bag
22	Bag in container	Long Beach	100	1,950	2.5	Cover came off at surface
23	Bag in container	Long Beach	100	1,950	2.5	Went down; had to be pulled way up
24	Bag in container	Long Beach	100	1,950	2.5	Cover came off near surface
25	Bag in container	Long Beach	100	1,950	2.5	Went down; had to be pulled part way up
26	Bag in container	Long Beach	100	1,300	2.0	Worked OK
27	Bag in container	Long Beach	100	1,300	2.0	Went down; had to be pulled part way up
28	Torpedo-shaped device	Long Beach	70	200	0.75	Went too far down before coming up
29	Torpedo-shaped device	Long Beach	100	200	1.0	Worked OK
30	Torpedo-shaped device	Long Beach	200	200	1.5	Went down; had to be pulled to within 50 ft of surface
31	Torpedo-shaped device	Long Beach	200	300	1.5	Worked OK

11 at Morris Dam in 100 ft of fresh water, and was tried in the ocean in Test 12.

In that test, the inside of the cavity had been coated with wax to provide a smooth surface. The bag became stuck to the wax, and did not emerge from the cavity until the apparatus was hoisted near the surface.

In Test 13, the wax was removed and the apparatus functioned properly. However, in this case the excess LiH was pushed out of the bag onto the ocean surface. The hydrogen gas that was generated exploded, and the lithium hydride burned.

In an effort to remedy this situation, Tests 14, 15, 16, and 17 were made, using the simpler U-frame test apparatus. In Test 14, only
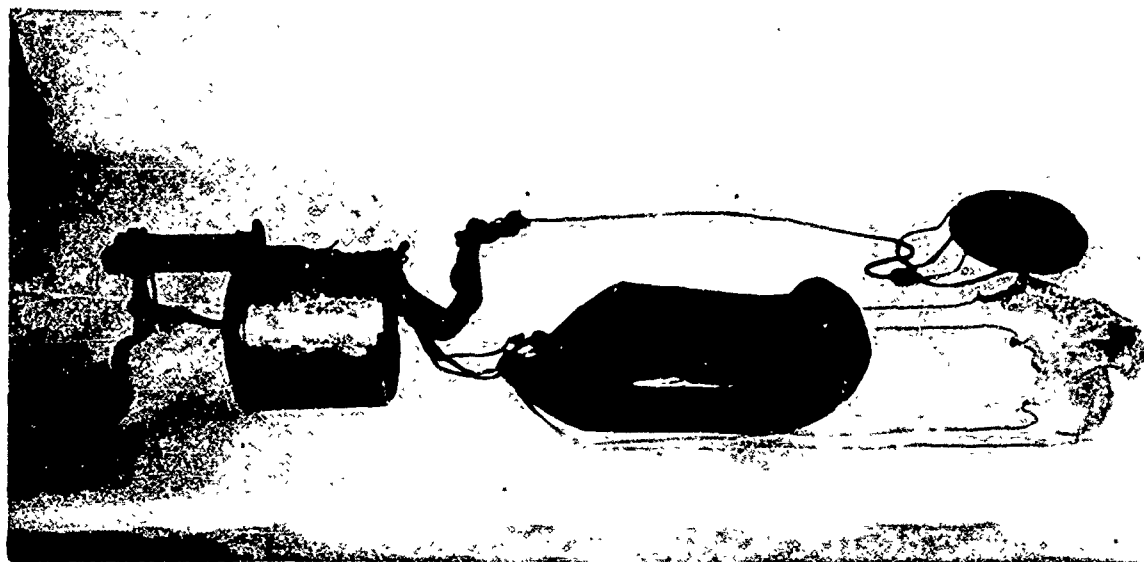
FIG. 5. Bag-in-Container Recovery Mechanism.

0.25 lb of LiH without oil was used, but the apparatus made a successful ascent. In Test 15, the bag became separated from the apparatus. In Tests 16 and 17, however, the LiH was mixed with SAE motor oil, and the apparatus worked with quantities of 1.0 and 1.5 lb of LiH without combustion. After the U-frame tests indicated that the heat problem was solved, Tests 18 and 19 were made successfully, with the complex apparatus and using 1.0 lb of LiH in oil, at a depth of 600 ft. The next two tests were at even greater depths, Test 20 at 1,200 ft and Test 21 at 2,600 ft. Test 20 was successful even though the force of the descending piston separated the lead weight and cover-release mechanism. In Test 21, the apparatus, negatively buoyant by 50 lb, ascended from 2,600 ft with no problems, using 1.75 lb of LiH. The residue left in the bag consisted of 1.125 lb of hard, black-charred lumps.

The next series of tests—22 through 27—were made using a slightly greater quantity of LiH, ranging from 2.0 to 2.5 lb. Only one test proceeded as planned. Two reactions were accidentally triggered near the surface; in three other tests, the apparatus had to be pulled part way to the surface before reaction would take place normally. Slowness of reaction in the latter instances probably allowed the apparatus to sink below the calculated recovery depth. The amount of LiH theoretically needed for any weight and depth may be computed from Fig. 6.

Simulated Torpedo Test Apparatus. To test the difficulties of packaging and operating a recovery device in an actual torpedo, an additional test apparatus was built (Fig. 7 and 8). This apparatus was designed not only to provide flotation, but also to slow the torpedo before inflation of the bag. A torpedo-shaped vehicle was used, with a hollow section enclosed by two round covers diametrically positioned to the axis of the vehicle's cylindrical hull. When the two covers are removed, in effect, a hole passes through the vehicle. The lower cover
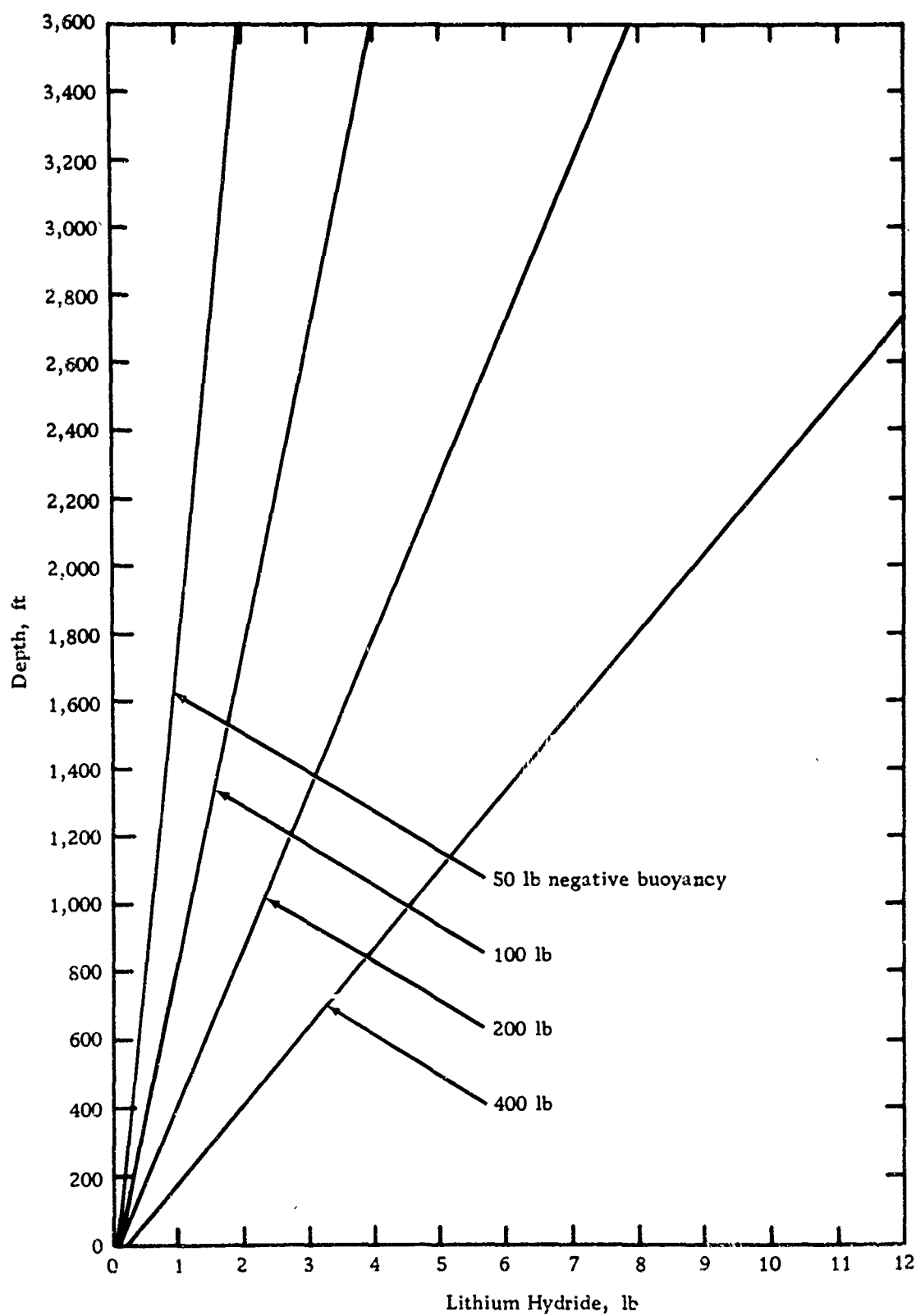
FIG. 6. Theoretical Amount of Lithium Hydride Needed to Recover Various Weights From Various Depths.
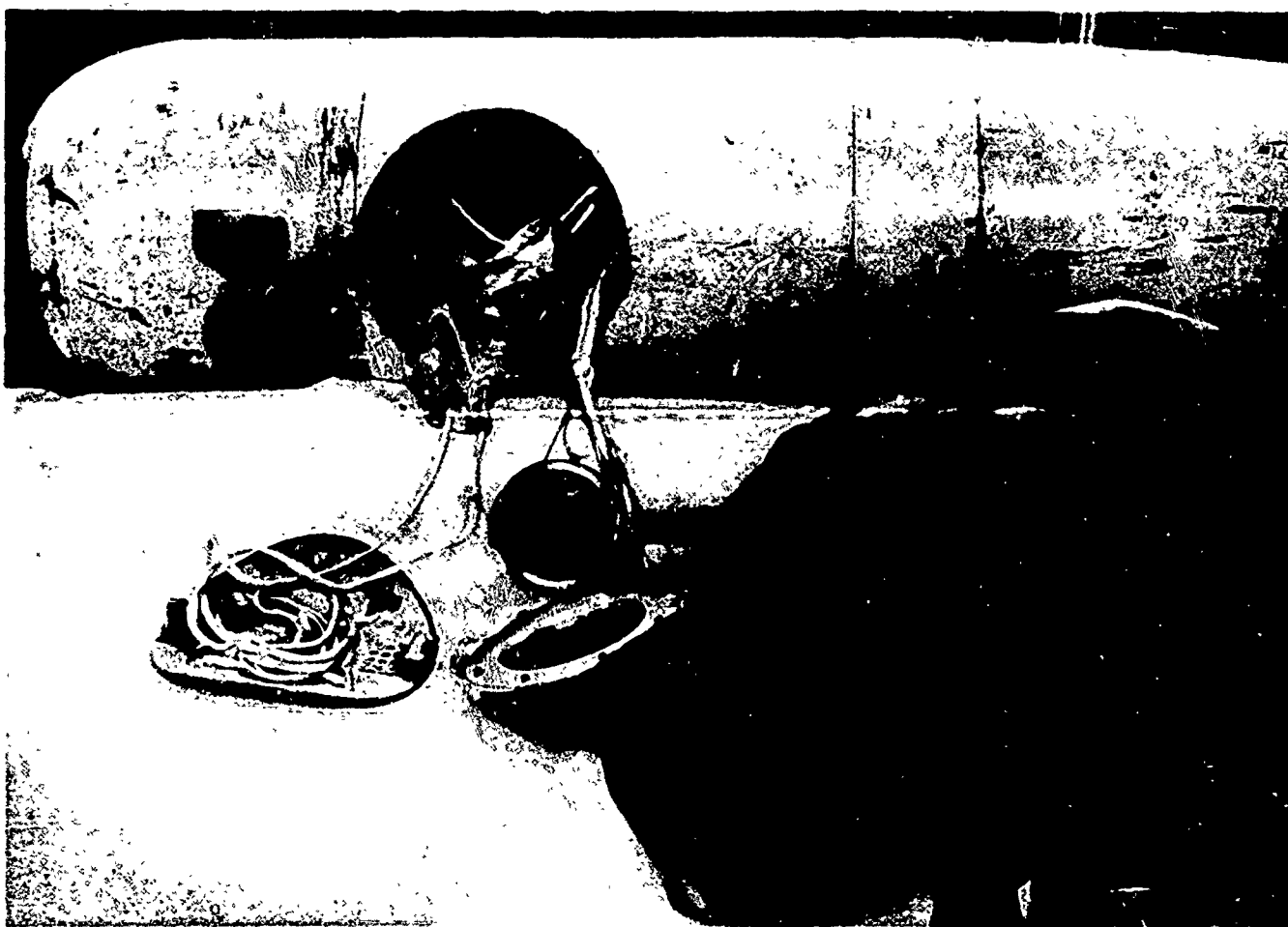
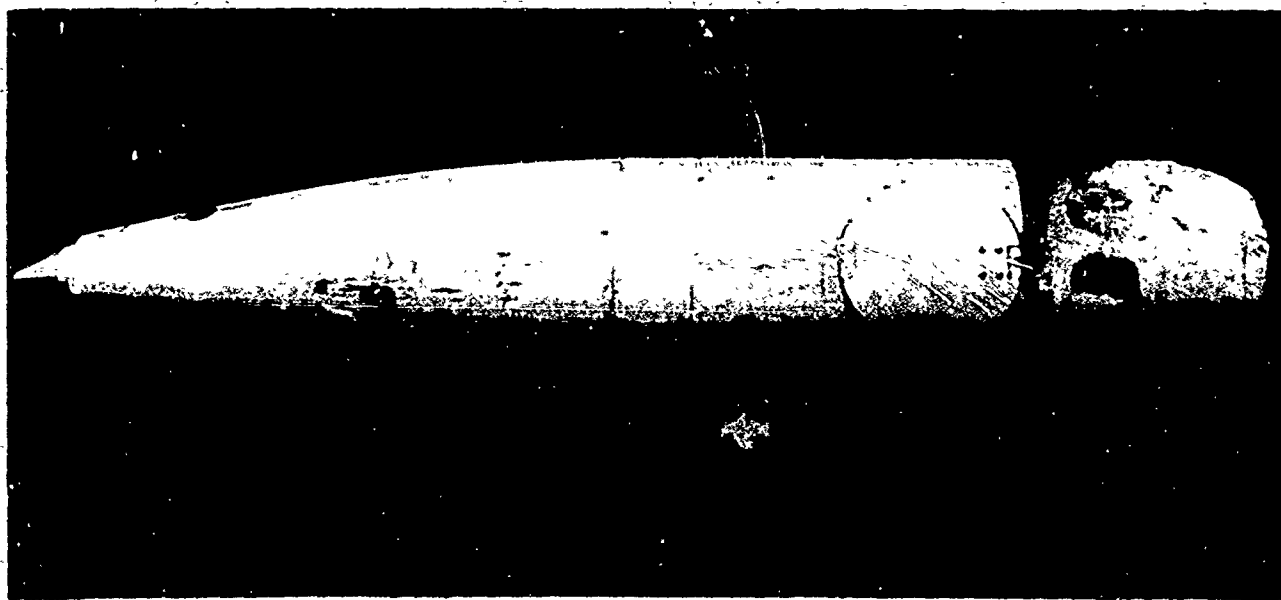FIG. 7. Detailed View of Recovery Mechanism Used in Torpedo-Shaped Device.

FIG. 8. Complete Torpedo-Shaped Recovery Device.

is hinged, and, when opened, acts as a brake and a rudder, turning the torpedo upward (this cover is represented as a dotted line in Fig. 3). The upper cover is used to pull the bag out, and also acts as a brake. The covers are unlatched by a hydraulic mechanism actuated by water pressure. The speed at which the new apparatus descends through the water (20 fps) is higher than that of earlier gear, and more closely simulates a moving torpedo.[1]

Tests 28, 29, 30, and 31 were made with the new apparatus. In the first two of these, the apparatus descended too far before becoming buoyant and starting up; in the third, the apparatus had to be pulled part way up before reaction would take place. The latter instance was probably due to the mouth of the bag not maintaining perpendicularity to the flow of water, so that inflow was inadequate and could not provide the amount of sea water necessary for the reaction to occur. An analysis indicated that the two lines used to hold the bag to the apparatus were inadequate in maintaining perpendicularity. Two additional lines were added, and Test 31 was successful (Fig. 9).
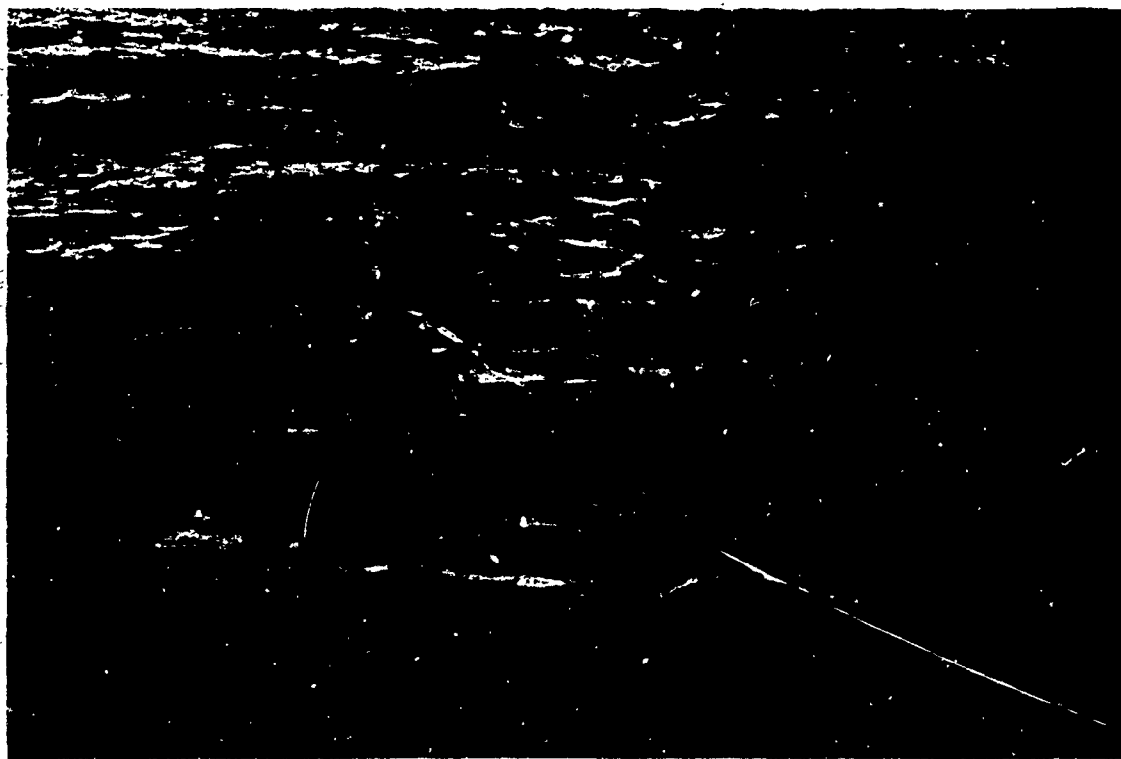

FIG. 9. Inflated Bag After Recovery in Ocean.

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[1] Detailed information on construction and operation of the test apparatus may be found in U. S. Patent 3,175, 525: Water-Activated Gas Buoyancy Device, issued 30 March 1965 to Gerrit DeVries.

Other Applications. A number of additional applications for hydrogen gas generated by the LiH–H_2O reaction are feasible, including the firing of torpedoes and rockets, and the blowing of ballast tanks, as well as the inflation of balloons. The reaction could be accomplished either by injecting LiH into a tank of water, or by placing the LiH in a deeply submerged wire cage and collecting the gas in a bag or compartment suspended above it.

CONCLUSIONS

The reaction of lithium hydride with sea water yields more high-pressure gas in any given weight and space than any other practical method. Tests have shown that pressure has little effect on the reaction, which goes to completion in a very short time provided at least 25 times as much water as lithium hydride by weight is employed. Variables investigated in connection with this reaction included completeness of reaction, effect of particle size, effect of pressure, effect of temperature, effect of sea water, effect of water—LiH ratio, and effect of additives. These investigations provided useful guidelines in the practical application of this reaction to torpedo recovery. In addition, the reaction was range-tested 31 times in four different configurations, each more closely simulating an actual torpedo recovery system than its predecessor. In all tests, the LiH reacted with the water and filled the bag with hydrogen. In 18 of the tests, the freely sinking unit came up without assistance. In the other tests, because of various mechanical difficulties, the unit had to be hauled up, partially or completely, by means of a line.

One of the configurations weighing 50 lb was successfully recovered from an ocean depth of 2,650 ft, and one of 100 lb was recovered from 1,300 ft. Another configuration of 200 lb was recovered from a depth of 300 ft.

Uses proposed for the high-pressure gas generated by this reaction include emergency blowing of ballast tanks, firing rockets and torpedoes, creating buoyancy for recovery devices, and inflating balloons.

NEGATIVE NUMBERS OF ILLUSTRATIONS

Fig. 1, none; Fig. 2, LHL-P 23038; Fig. 3, none;
Fig. 4, LHL-P 23428; Fig. 5, LHL-P 23721-3;
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13. ABSTRACT   Tests were made to determine the quantity and rate of gas produced from the lithium hydride—sea water reaction. The effects of particle size, pressure, temperature, water composition, water—lithium hydride ratio, and additives to the lithium hydride were investigated. In addition, a gas inflation system for torpedo recovery using lithium hydride was designed and tested in the ocean. Lithium hydride and water were found to react completely at a ratio of 25 (or more) parts water: 1.0 part lithium hydride, by weight. The effects of other variables on the reaction were minor. The lithium hydride torpedo-recovery system successfully raised 50 pounds from a depth of 2,600 feet.

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